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ANNUAL REPORT

SODIUM SULFATE

By Dennis S. Kostick

1990

U.S. DEPARTMENT OF THE INTERIOR

BUREAU OF MINES

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U.S.
DEPARTMENT
OF THE
INTERIOR

Manuel Lujan, Jr.
Secretary

BUREAU
OF
MINES

T S Ary
Director

July 1991

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COVER PHOTO:
The Westend facility of North American Chemical Co. (formerly Kerr-McGee Chemical Corp.) is the largest producer of natural sodium sulfate in the United States. It is at Searles Lake, by Trona, CA.

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SODIUM SULFATE

By Dennis S. Kostick

Mr. Kostick, a physical scientist with 12 years of U.S. Bureau of Mines experience, has been the commodity specialist for sodium sulfate since 1979. Domestic survey data were prepared by Carleen Militello, mineral data assistant; and international data tables were prepared by William Zajac, Chief, Section, International Minerals.

Sodium sulfate is produced from natural sources or recovered as a byproduct from various manufacturing processes and has several important and useful applications in various consumer products. In a survey of the top 50 basic organic and inorganic chemicals made in the United States, sodium sulfate ranked 48th in terms of quantity produced.[1]

Beginning with this report, all data will be reported in metric units to comply with Public Law 100-418 of August 23, 1988. This Federal law required all Federal agencies to use the metric system of measurement by the end of fiscal year 1992. Although the use of the metric measurement standards was authorized by law since 1866 (Act of July 28, 1866; 14 Statute 339) and the United States was an original signatory party to the 1875 Treaty of the Meter (20 Statute 709), the United States has been the only industrially developed nation that has not universally converted to the metric system from the English system of measurements. As foreign trade of soda ash increases and foreign participation in U.S. joint mining ventures continues, communicating information with an international standard of measurement becomes more important.

DOMESTIC DATA COVERAGE

Domestic production and inventory data for natural sodium sulfate are developed by the U.S. Bureau of Mines from monthly and annual surveys of U.S. operations. Of the three natural sodium sulfate operations to which a survey request was sent, all responded, representing 100% of the natural sodium sulfate data used in this report.

Synthetic, also known as byproduct, sodium sulfate data were collected by the U.S. Department of Commerce, Bureau of the Census, from monthly and annual surveys (aggregate data published in Current Industrial Reports, Inorganic Chemicals, M28A and MA28A) of companies engaged in recovering and selling byproduct sodium sulfate. Any revised Census Bureau data have been included using most recent Census Bureau statistics. These data are aggregated with U.S. Bureau of Mines natural sodium sulfate data and included in several tables.

BACKGROUND

Natural sodium sulfate was known to have been used as a medicine as early as the 16th century. It was first accurately described in 1658 by Johann Rudolf Glauber, a German chemist whose name is still associated with the hydrated crystal, Glauber's salt ($Na_2SO_4 \cdot 10H_2O$), and the anhydrous mixed sulfate, Glauberite ($Na_2SO_4 \cdot CaSO_4$).

Glauber and other researchers prepared sodium sulfate by reacting common salt with sulfuric acid. The invention of the Kraft process for making pulp and paper in 1880 provided the first major industrial market for sodium sulfate.

Definitions, Grades, and Specifications

The following terms are used in the sodium sulfate industry:

Anhydrous Sodium Sulfate.—Refined sodium sulfate or the mineral thenardite (Na_2SO_4). Named for the French chemist, Louis Jacques Thenard, thenardite is a colorless to white mineral with a specific gravity of 2.67 and a hardness of 2.5 to 3. Because of its whiteness and purity, it is used in detergents, pharmaceuticals, dyestuffs, glass, and ceramic glazes. Commercial grade material has a bulk density of about 1.23 grams per cubic centimeter (77 pounds per cubic foot).

Byproduct Sodium Sulfate.—Synonymous with synthetic sodium sulfate. It is recovered as a byproduct from various chemical and textile manufacturing processes.

Glauber's Salt.—Same as the mineral mirabilite (Latin "sal mirabile" or "wonderful salt"), sodium sulfate decahydrate ($Na_2SO_4 \cdot 10H_2O$). The mineral contains 55.9% water of crystallization and forms opaque to colorless needlelike crystals.

High Purity.—Refers to anhydrous sodium sulfate with a purity of 99% or greater. Usually sold to detergent, glass, and textile industries.

Low Purity.—Some processes occasionally produce sodium sulfate that does not meet certain physical or color specifications required by certain consumers despite being a chemically pure product. This grade of sodium sulfate is generally sold to sectors that are not as concerned about whiteness or particle size, such as the pulp and paper industry, at reduced prices.

Natural Sodium Sulfate.—Sodium sulfate obtained from mining crystalline sodium sulfate-bearing minerals or from sodium sulfate-bearing brines.

Salt Cake.—Normally refers to impure sodium sulfate containing 90% to 99% Na_2SO_4. Because of its impurity or possible discoloration, it usually is sold only to the pulp and paper industry.

Synthetic Sodium Sulfate.—Same as byproduct sodium sulfate.

Sodium sulfate made from natural brine usually contains less than 0.5% total impurities, but that produced as a byproduct of other manufacturing may contain much larger quantities. The

TABLE 1

SALIENT SODIUM SULFATE STATISTICS

(Thousand metric tons and thousand dollars)

	1986	1987	1988	1989	1990
United States:					
Production[1]	763	725	r743	r685	665
Value[2]	$72,419	$69,289	r$64,545	r$62,703	$64,244
Exports	101	111	77	62	62
Value	$10,183	$10,554	$8,737	$6,241	$6,704
Imports for consumption	171	125	136	173	162
Value	$13,829	$10,363	$11,962	$13,990	$13,155
Stocks, Dec. 31: Producers'	65	50	54	24	39
Apparent consumption	796	754	r798	r826	750
World: Production	r4,609	r4,800	r4,937	r5,009	e4,998

eEstimated. pPreliminary. rRevised.

[1]Includes natural and synthetic. Total production data for synthetic sodium sulfate, obtained from the Bureau of the Census, was revised in Dec. 1990 M28A Inorganic Chemicals, Current Industrial Report.

[2]The value for synthetic sodium sulfate is based upon the average value for natural sodium sulfate.

material meeting U.S. Pharmacopeia (U.S.P.) specifications and that intended for glassmaking must contain at least 99% sodium sulfate. In addition, glassmakers' grade must be low in iron and heavy metals. Technical grades of sodium sulfate may have from 2% to 6% impurities. Purchases of detergent or rayon-grade sodium sulfate are based primarily on whiteness. Its sodium chloride content may be between 1.5% and 2.0%, and its iron content between 60 and 100 parts per million.

Industry Structure

Three companies produced natural sodium sulfate from a total of three plants in California, Texas, and Utah. The domestic natural sodium sulfate industry supplied about one-half of the total output of U.S. sodium sulfate. Because of the location of these plants, most natural sodium sulfate is marketed in the West and southern gulf areas. Byproduct material was supplied by 15 companies operating 16 plants primarily in the Midwest and Mid-Atlantic regions. Total rated production capacity in 1990 was 836,000 tons, and the industry operated at 80% of this capacity.

Geology-Resources

Sodium is the sixth most abundant element in the Earth's crust. Sodium sulfate-bearing mineral deposits are geologically young, mainly of post-glacial age. Sodium sulfate is widespread in occurrence and is a common component of seawater and many saline or alkaline lakes. Economic reserves of natural sodium sulfate are estimated at 3.3 billion tons worldwide. With world production of natural sodium sulfate averaging about 2.6 million tons per year, supplies are sufficient to meet anticipated demand for several centuries. The quantity of synthetic sodium sulfate is dependent on the longevity of the manufacturing firms recovering byproduct sulfate.

Surface depressions or lakes that have no outlets and are fed by spring waters flowing over volcanic rocks containing sulfide minerals often yield soluble sulfide salts that are oxidized by contact with the air to produce sulfates. Some minerals over which the spring water may flow contain the sulfates directly, such as bentonite or gypsum. When an inland lake of this type evaporates and becomes highly concentrated in salts, one of the first salts to precipitate would be mirabilite, also known as Glauber's salt, which has very poor solubility at low temperatures. During seasonal temperature variations, the sulfate will precipitate preferentially to the lake bottom.

Thenardite and mirabilite are the only sodium sulfate minerals that are commercially important. Many economic deposits of sodium sulfate are in the form of crystalline beds of mirabilite such as those found in Canada and the U.S.S.R., which has the world's largest sodium sulfate resource in the Kara-Bogaz-Gol Gulf. Because mirabilite converts to thenardite when exposed to air, its outer surface may develop a thenardite crust. Some buried sedimentary formations contain very large deposits of thenardite and glauberite, such as the deposit in Villarrubia de Santiago in Spain.

Sodium sulfate is also found dissolved in underground brines in California, Texas, and other parts of the world. The sulfate is usually converted to mirabilite when extracted from the brine by mechanical refrigeration techniques.

Technology

The technology to mine and process natural sodium sulfate involves mechanical refrigeration or natural chilling to induce crystallization followed by dissolution, filtration, evaporation, and drying. Recovery of byproduct sodium sulfate from chemical processes involves various techniques.

Mining.—Sodium sulfate is extracted from the upper level of the Searles Lake brine in California and is treated separately from the carbonate-rich lower level and mixed layer brines. The subterranean sodium sulfate-bearing brines in western Texas are the simplest of the domestic brine deposits. Mechanical refrigeration is used to extract Glauber's salt crystals from the brine. The Great Salt Lake in Utah also contains valuable quantities of sodium sulfate. Brine from the most concentrated northwest segment of the lake is pumped into solar evaporation ponds on the eastern shore of the lake where sodium chloride first precipitates as the water evaporates. Sodium sulfate crystals precipitate in a fairly pure state when winter weather cools the brine to –1° to 4° C (30° to 40° F). The crystals are picked up by large earth-moving machinery and stored outdoors until further processing to anhydrous sodium sulfate can take place.

Processing.—At Searles Lake, the brine is first cooled at about 16° C (60° F) to precipitate borax crystals, which are removed from the system for subsequent further processing and sale. A second cooling to about 4° C (40° F) precipitates the sodium sulfate in the form of Glauber's salt. These crystals are separated from the brine on a rotating drum filter. They are then redissolved in fresh

TABLE 2

PRODUCERS OF NATURAL AND SYNTHETIC SODIUM SULFATE IN 1990

Product and company	Plant nameplate capacity (thousand metric tons)	Plant location	Source
Sodium sulfate, natural:			
Great Salt Lake Minerals & Chemicals Corp.	45	Ogden, UT	Salt lake brine.
North American Chemical Co.,[1] Westend plant	218	Trona, CA	Dry lake brine.
Ozark-Mahoning Co.[2]	141	Seagraves, TX	Do.
Total	404		
Sodium sulfate, synthetic:			
BASF	34	Lowland, TN	Rayon manufacture.
North American Rayon Corp.	14	Elizabethton, TN	Do.
Climax Chemical Co.	45	Hobbs, NM	Hydrochloric acid manufacture.
Courtaulds North America Inc.	45	La Moyne, AL	Rayon manufacture.
Cyprus Specialty Metals	16	Kings Mountain, NC	Lithium carbonate.
W. R. Grace & Co. Organic Chemicals Div.	8	Nashua, NH	Chelating agents.
Green Bay Packaging	10	Green Bay, WI	Byproduct.
Hoffman-La Roche Inc.	14	Belvidere, NJ	Ascorbic acid manufacture.
J. M. Huber	32	Etowah, TN	Silica pigment.
Do.	14	Havre de Grace, MD	Do.
Indspec Chemical Corp.	35	Petrolia, PA	Resorcinol manufacture.
Lithium Corp. of America	41	Bessemer City, NC	Lithium carbonate.
Occidental Chemical Corp.	109	Castle Hayne, NC	Sodium dichromate manufacture.
Public Service of New Mexico	6	Waterflow, NM	Fluegas desulfurization.
Teepak Inc.	6	Danville, IL	Cellulose manufacture.
Texaco Chemical Co.	3	Delaware City, DE	Fluegas desulfurization.
Total	432		
Grand total	836		

[1]Purchased Nov. 30, 1990, from Kerr-McGee Chemical Corp.
[2]Ozark's Brownfield plant, owned by Atochem North America (formerly Pennwalt), was placed on standby in Sept. 1987, 64,000 tons of capacity is not included in total industry capacity.

water in a vacuum crystallizer. After the second separation and drying, the crystals are about 98.2% sodium sulfate. Additional treatment can obtain a 99.3% purity. Major impurities remaining are sodium chloride, sodium carbonate, and boron.

In Texas, after the crystals are processed in rotary drum vacuum filters and washed, they are melted and dehydrated using mechanical vapor recompression evaporators, which are more energy efficient than triple effect evaporators or submerged gas burners. Final classifying, centrifuging, drying in rotary kilns, and screening converts the Glauber's salt to marketable anhydrous sodium sulfate of 99.7% purity.

Purification and dehydration procedures at the facility on the Great Salt Lake are similar to those of other sodium sulfate plants. The final product results in a purity between 99.5% to 99.7%.

Sodium sulfate is also produced as a byproduct of the production of ascorbic acid, boric acid, cellulose, chromium chemicals, lithium carbonate, rayon, resorcinol, and silica pigments. It is also recovered from certain flue gas desulfurization operations. The Mannheim and Hargreaves furnace processes also produce byproduct sodium sulfate. In the Mannheim furnace, salt and sulfuric acid are reacted to form hydrogen chloride (HCl) and sodium sulfate. The Hargreaves furnace produces HCl and sodium sulfate by the reaction of sulfur dioxide, sodium chloride, air, and water. The Mannheim process is the major method used in Europe, but its use in the United States has decreased considerably since less expensive methods to produce HCl became available.

Recycling.—Because of environmental concerns regarding sulfur emissions from pulp and paper mills, many Kraft pulpers were installing pollution abatement equipment to reduce sulfur losses in the pulping process. This will result in more sodium sulfate being recycled and less used in batch makeup solutions.

Byproducts and Coproducts

The brines of Searles Lake in California contain sodium sulfate as well as coproduct borax, potassium chloride, sodium chloride, and soda ash. The Great Salt Lake in Utah is a source of magnesium compounds, potassium sulfate, sodium chloride, as well as sodium sulfate. The brines in Texas do not yield any secondary products.

Some manufacturers of ascorbic acid, boric acid, cellulose, chromium chemicals,

TABLE 3

WORLD NATURAL SODIUM SULFATE RESERVES AND RESERVE BASE

(Million metric tons)

	Reserves	Reserve base[1]
North America:		
Canada	84	272
Mexico	165	227
United States	857	1,361
Total	1,106	1,860
Europe:		
Spain	180	272
U.S.S.R.	1,814	2,268
Total	1,994	2,540
Africa:		
Botswana	188	227
World total	[2]3,300	4,600

[1]The reserve base includes demonstrated resources that are currently economic (reserves), marginally economic (marginal reserves), and some of those that are currently subeconomic (subeconomic resources). These definitions of reserves and reserve base are published in U.S. Geological Survey Circular 831, "Principles of a Resource/Reserve Classification for Minerals."

[2]Data do not add to total shown because of independent rounding.

NOTE.—Resources of sodium sulfate are known to also exist in Antarctica, Argentina, Chile, India, Iran, Italy, Mongolia, Romania, the Republic of South Africa, and Turkey. Production of synthetic sodium sulfate is dependent on the supply and demand of the primary product.

lithium carbonate, rayon, resorcinol, and silica pigments produce sodium sulfate as a byproduct of the process. The sodium sulfate is considered a waste product but has marketability.

Economic Factors

Prices.—Producers of natural sodium sulfate tend to market and sell most of their own product, but most synthetic producers use major chemical distributors or chemical supply companies as sales agents. The principal product made and sold by the synthetic sodium sulfate producer is the primary economic factor. Because sodium sulfate is considered a waste product, it will be sold at a price that ensures prompt sales. This practice tends to set the rates at which the natural product can be sold.

The list prices quoted in trade journals or by producers of all grades of sodium sulfate differ from the annual average values reported by the U.S. Bureau of Mines. The value represents the combined

FIGURE 1

PRODUCTION AND PROCESSING OF SODIUM SULFATE

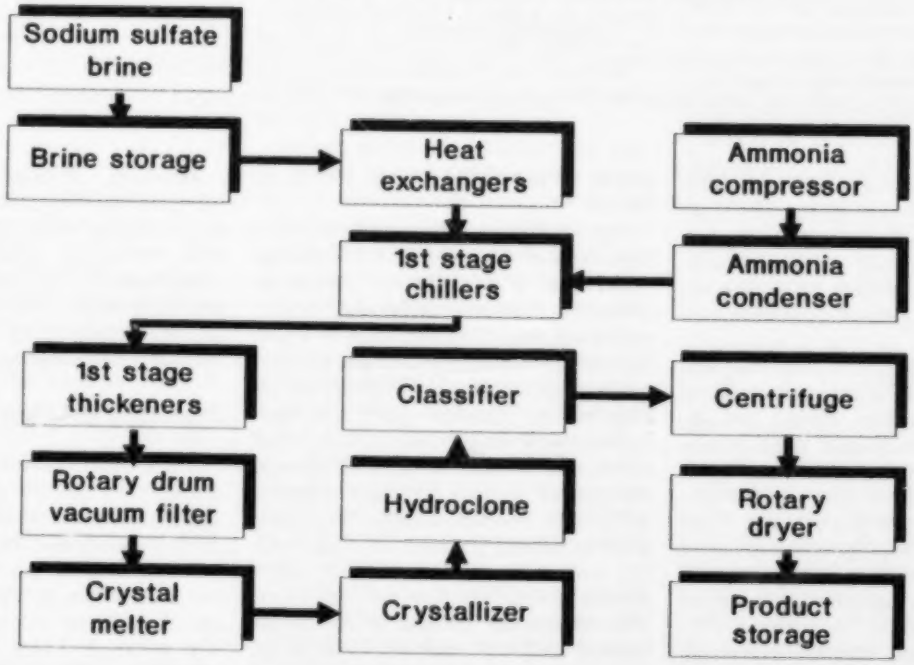


TABLE 4

TIME-VALUE RELATIONSHIPS FOR SODIUM SULFATE

Year	Average annual value,[1] dollars per ton			
	Natural sodium sulfate			
	Actual value		Based on constant 1990 dollars[2]	
	Short ton	Metric ton	Short ton	Metric ton
1970	18.28	20.15	57.23	63.09
1971	16.00	17.64	47.39	52.24
1972	16.26	17.92	45.98	50.68
1973	17.26	19.03	45.85	50.54
1974	23.99	26.44	58.42	64.40
1975	41.48	45.72	91.98	101.39
1976	49.25	54.29	102.64	113.14
1977	46.09	50.81	90.06	99.27
1978	46.06	50.77	83.89	92.47
1979	55.69	61.39	93.17	102.70
1980	62.42	68.81	95.78	105.58
1981	71.03	78.30	99.37	109.54
1982	83.00	91.49	109.15	120.32
1983	93.30	102.85	118.08	130.16
1984	92.16	101.59	112.53	124.04
1985	92.19	101.62	109.31	120.49
1986	86.11	94.92	99.50	109.68
1987	86.72	95.59	97.14	107.08
1988	78.81	86.87	85.44	94.18
1989	83.05	91.55	86.47	95.32
1990	87.66	96.63	87.66	96.63

[1]Based on the average valuation by producers of their annual total production and reported sales. The values incorporate the price differences charged by producers for the same finished product sold in bulk at the plant.
[2]From final 1990 implicit price deflators for gross national product, by the Council of Economic Advisors. Based on 1982 = 100.

amount of total revenue of domestic natural sodium sulfate sold at list prices, spot prices, long-term contracts, discounts, and export divided by the aggregated quantity of sodium sulfate sold. The published value does not necessarily correspond to the posted list price.

Tariffs.—Import tariffs serve to protect the interests of domestic producers for particular products. For sodium sulfate, a 32.5-cent-per-ton tariff is imposed on imported anhydrous sodium sulfate from countries having most favored nation (MFN) status and $2.95 per ton from those with non-MFN status. There are no import tariffs on imported salt cake, regardless of the country of origin.

Royalties.—Sodium sulfate mined on Federal lands is subject to the Mineral Leasing Act of 1920, which provides for royalty payments to the U.S. Government. The royalty is 5% of the quantity or gross value of the output of the product at the point of shipment to market. Each Federal lease also has other costs, such as bonds, acreage rental fees, sodium prospecting permit application fees, and permit bonds. The Searles Lake sodium sulfate deposit is the only resource with active operations that has any Federal leases. Because of the variety of the brine constituents, the operator has a commingling agreement with the U.S. Government to compute royalties.

Depletion Provisions.—Legislation passed by the U.S. Government provides an allowance for the depletion of natural resources, notably timber and minerals. The depletion allowance is an important inducement for companies willing to accept the risk and high cost of mining development. The concept of depletion allowances for minerals is similar to the depreciation of other assets. Although cost depletion and percentage depletion are two methods used to compute depletion deductions, most companies prefer to use the latter. About 100 mineral categories are entitled to percentage depletion. The rates range between 5% and 22% of the gross income from the mineral property, depending on the mineral and location (foreign or domestic), and are subject to a limitation of 50% of the net income of the property. The mineral depletion allowance for natural sodium sulfate is 14% for U.S. companies mining from domestic or foreign sources.

Operating Factors

Operating factors are different for mining companies producing natural sodium sulfate compared with manufacturing facilities recovering byproduct sodium sulfate. The quantity of synthetic sodium sulfate recovered is directly associated with the production capabilities of the primary industry (e.g., rayon, lithium carbonate, etc.) and the sulfate recovery rates.

Environmental Requirements.—Land usage may become a problem when sodium sulfate is obtained by solar evaporation, as in the case of the Great Salt Lake brines. Large areas of relatively flat land are required to allow for adequate concentration and evaporation. When land values are high, the capital required for land acquisition may increase operating costs. Disposal of the waste liquors from which sodium sulfate was extracted may develop into a major groundwater discharge problem in some areas. Reinjection of spent solutions into underground source strata is expensive but often is the only acceptable method of disposal.

Because sodium sulfate is water-soluble, most releases of sodium sulfate to the environment affect water quality rather than air or land quality. These releases are mainly from Kraft pulp mills, which typically discharge between 5 to 15 million kilograms (11 to 33 million pounds) of sodium sulfate per year per site. The resulting drinking water concentrations have been estimated as high as 38.8 milligrams per liter, which is significantly below the maximum concentration level of 250 milligrams per liter set by the National Secondary Drinking Water Standard.

Problems associated with chemical effluents discharged from manufacturing plants that recover sodium sulfate have also caused environmental concerns not attributed to sodium sulfate. The second largest byproduct sodium sulfate facility in the United States at Front Royal, VA, owned by Avtex Fibers Inc., was closed in late 1989 by Federal and State regulatory agencies because of contaminated water discharges containing carbon disulfide and polychlorinated biphenyls (PCB's). These toxic chemicals were produced from rayon manufacture, not sodium sulfate recovery.

Toxicity.—Sodium sulfate was deleted in early 1989 from the list of toxic chemicals under section 313 of Title III of the Superfund Amendments and Reauthorization Act of 1986. The U.S. Environmental Protection Agency determined that there was no evidence that sodium sulfate caused, or could reasonably be anticipated to cause, adverse human health or environmental effects as specified in the act.

Employment.—According to the Bureau of Labor Statistics and industry sources, approximately 300 persons are employed in mining and processing natural sodium sulfate in the United States. No data are available on the number of personnel employed in recovering byproduct sodium sulfate.

Energy Requirements.—The energy requirements to mine natural sodium sulfate are minimal compared with the amount of energy required to process it.

An early U.S. Bureau of Mines energy survey reported that 4.5 million British thermal units (Btu's) were required to produce 1 ton of natural sodium sulfate. With the interest in conserving energy, some technical improvements, such as the installation of mechanical vapor recompression crystallizers, have reduced the overall energy requirement to slightly less than 2 million Btu's per ton of sulfate produced.

Transportation.—All natural sodium sulfate is shipped in bulk or in bags by either rail or truck. The mode of transportation depends on the location of the customer, quantity purchased, and difference in freight rates. Because of the location of the natural producers in the West and Southwest, very little natural sodium sulfate is shipped to the East because transportation rates reduce its competitiveness with synthetic sodium sulfate. Consumers in the Midwest and East tend to rely on synthetic sodium sulfate produced in various Midwest and Southern locations.

ANNUAL REVIEW

U.S. production of sodium sulfate decreased about 3% in 1990, but overall domestic apparent consumption declined more than 9%. The downturn in production was attributed to depressed economic conditions that affected some of the industries that recover byproduct sodium sulfate and the effects of the shutdown of Avtex Fibers Inc. the previous year. Although the United States is one of the largest producers in the world of natural and synthetic sodium sulfate, its share has decreased from 23% of world production total in 1980 to 13% in 1990.

Issues

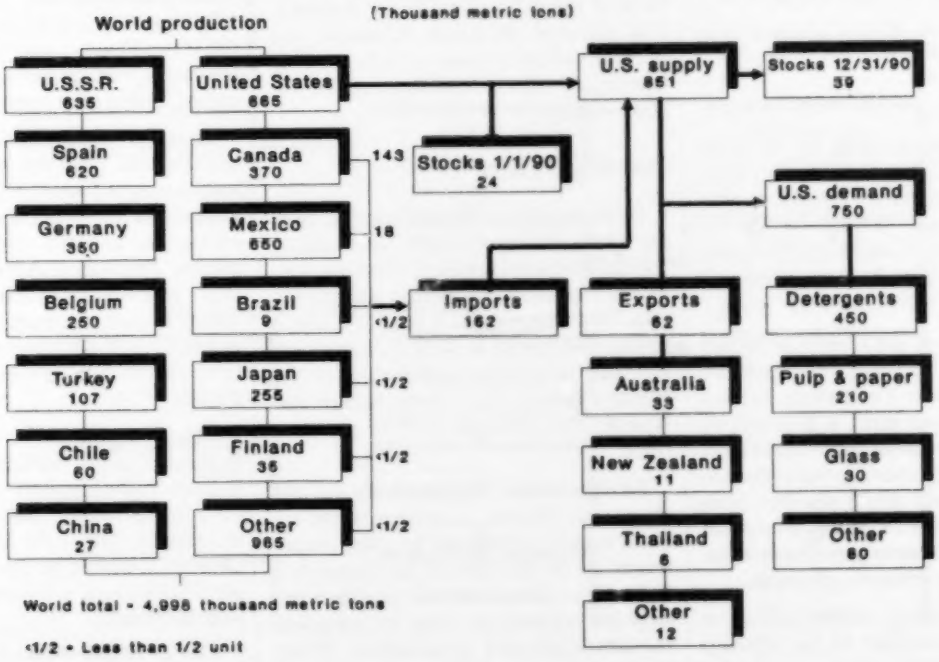
The soap and detergent industry, the largest consumer of sodium sulfate, began reformulating powdered home laundry detergents that substantially reduced the quanity of sodium sulfate used as filler. The growing national environmental awareness regarding the volume of packaging material discarded to landfills prompted certain detergent manufacturers to begin making superconcentrated or compact products that are packaged in smaller containers. This reduction in package size will minimize the amount of landfill waste but will also reduce the quantity of sodium sulfate used in powdered detergents.

The use of superconcentrates also has had a psychological affect on some of the public. Consumers traditionally have believed that adding more than the recommended quantity of powdered detergent to a washload would make clothes more cleaner. Although the technology to make superconcentrated detergents has existed for several years, detergent manufacturers could not counter the consumers' long-standing belief that "more is better." Interest in the environment has made it possible for detergent manufacturers to invoke this change in perception.

Sodium sulfate consumption by the pulp and paper industry remained firm despite all the publicity regarding the

FIGURE 2

SODIUM SULFATE SUPPLY-DEMAND RELATIONSHIPS, 1990



environmental effects of discharged pulp bleaching chemicals.

Production

U.S. production of sodium sulfate decreased about 3% in 1990 primarily because of the closure in 1989 of Avtex Fibers Inc., a rayon manufacturer in Front Royal, VA, that recovered byproduct sodium sulfate. Avtex was the second largest synthetic sodium sulfate producer in the United States with an annual production capacity of 77,000 tons.

North American Chemical Co., a company formed by a group of investors led by D. George Harris and Associates, purchased the Kerr-McGee Chemical Corp. sodium sulfate operation at Searles Lake in Trona, CA, for a reported $210 million in November 1990.[2] Oriental Chemical Industries of the Republic of Korea was one of the investors that acquired about 27% of the operation. In addition to sodium sulfate, the operation produces soda ash, salt, and various boron and potassium compounds. Harris and Associates was affiliated with Great Salt Lake Minerals and Chemicals Corp., which also produced natural sodium sulfate in Utah.

The United States was the largest producer of total sodium sulfate, representing about 13% of the world total, followed by Mexico and the U.S.S.R. with about 13% each; Spain, 12%; and Canada, 7%. These five countries accounted for approximately 58% of the world's output of total sodium sulfate, based on obtainable production data.

Consumption and Uses

Domestic consumption of sodium sulfate decreased about 9% because of environmental considerations, rather than economic conditions, affecting users of sodium sulfate. Imports for consumption of anhydrous sodium sulfate, primarily from Canada and Mexico, also declined.

About 60% of the total sodium sulfate consumed in the United States is for use as a filler in powdered laundry detergents. Many areas in the country have adopted phosphate bans or limitations because phosphatic detergents contribute to the environmental problems of eutrophication. The affected areas represent about

TABLE 5

SODIUM SULFATE SUPPLY-DEMAND RELATIONSHIPS[1]

(Thousand metric tons)

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
WORLD PRODUCTION											
United States	1,033	1,008	784	776	791	736	763	725	r743	r685	665
Rest of World	3,498	3,693	3,337	3,306	3,611	3,773	r3,846	r4,075	r4,194	r4,324	e4,333
Total	4,531	4,701	4,121	4,082	4,402	4,509	r4,609	r4,800	r4,937	r5,009	e4,998
COMPONENTS AND DISTRIBUTION OF U.S. SUPPLY											
Domestic sources	1,033	1,008	784	776	791	736	763	725	r743	r685	665
Imports	209	249	357	311	240	177	171	125	136	173	162
Industry stocks, Jan. 1[2]	26	30	60	27	44	54	28	65	50	54	24
Total U.S. supply	1,268	1,287	1,201	1,114	1,075	967	962	915	r929	r912	851
Distribution of U.S. supply:											
Exports	117	112	101	83	69	108	101	111	77	62	62
Industrial demand	1,121	1,115	1,073	987	952	831	796	754	r798	r826	750
Industry stocks, Dec. 31[2]	30	60	27	44	54	28	65	50	54	24	39
U.S. DEMAND PATTERN[e]											
Glass	67	62	54	50	49	48	48	r45	r48	r33	30
Pulp and paper	538	508	490	464	454	445	r239	r226	r239	r231	210
Soaps and detergents	437	435	426	425	363	318	r414	r392	r415	r495	450
Other[3]	79	110	103	48	86	20	r95	r91	r96	67	60
Total U.S. primary demand	1,121	1,115	1,073	987	952	831	796	754	r798	r826	750
VALUES[4]											
Average annual value per short ton[5]	62.42	71.03	83.30	93.30	92.16	92.19	86.11	86.72	78.81	83.05	87.66
Average annual value per metric ton	68.81	78.30	91.49	102.85	101.59	101.62	94.92	95.59	86.87	91.55	96.63

[e]Estimated using data from "Chemical Profile" issues on sodium sulfate by Chemical Marketing Reporter for 1980, 1983, 1986, and 1989. [r]Revised.

[1]Natural and synthetic except where noted. Synthetic sodium sulfate data obtained from the Bureau of the Census are revised periodically and may differ from previous published reports by the U.S. Bureau of Mines. World production data also are periodically revised on receipt of updated information.

[2]Natural sodium sulfate only.

[3]Includes ceramics, chemicals (potassium sulfate, sodium hyposulfite, sodium sulfide, sodium silicate, and sodium aluminum sulfate), feed supplements, printing inks, sulfonated oils, textile dyeing, veterinary medicines, and viscose sponges.

[4]Dollars per ton for natural sodium sulfate, f.o.b. mine or plant.

[5]Although data from 1990 and thereafter will be published in metric units, historical values based on short tons will continue to be published for reference.

TABLE 6

SYNTHETIC AND NATURAL SODIUM SULFATE[1] PRODUCED IN THE UNITED STATES

(Thousand metric tons and thousand dollars)

Year	Synthetic and natural[2] (quantity)			Natural	
	Lower purity[3] (99% or less)	High purity	Total	Quantity	Value
1986	328	435	763	359	34,102
1987	312	414	[4]725	346	33,086
1988	r312	431	r743	361	31,377
1989	r291	r394	r685	340	31,104
1990	305	360	665	349	33,748

rRevised.
[1]All quantities converted to 100% Na_2SO_4 basis.
[2]Current Industrial Reports, Inorganic Chemicals, Bureau of the Census. Revisions from Dec. 1990 M28A, p. 1.
[3]Includes Glauber's salt.
[4]Data do not add to total shown because of independent rounding.

TABLE 7

SODIUM SULFATE YEAREND PRICES

(Per ton)

	1989	1990
Sodium sulfate (100% Na_2SO_4):		
East, bulk, carlot, works, freight equalized	$113.00–$114.00	$113.00–$114.00
Gulf, bulk, carlot, same basis	90.00– 100.00	105.00
West, bulk, carlot, same basis	117.00	122.00
Salt cake (100% Na_2SO_4):		
East, bulk, f.o.b. works	65.00– 98.00	62.00
West, same basis	90.00– 99.00	—

Sources: Chemical Marketing Reporter, Current Prices of Chemicals and Related Materials, v. 237, No. 1, Jan. 1, 1990, p. 39; and v. 238, No. 27, Dec. 31, 1990, p. 31.

33% of the U.S. population. In response to this environmental issue, detergent manufacturers continued reformulating their detergents by switching from sodium tripolyphosphate (STPP) to tetrasodium pyrophosphate, which has the same building power as STPP but requires less to be used, thereby reducing the amount of phosphate released into the environment. These reformulations used more sodium sulfate as filler, which was beneficial to the sodium sulfate industry.

Sodium sulfate consumption increased in the Kraft pulping industry because of the rise in demand for paper products and the high prices of caustic soda, which is an alternative to sodium sulfate when prices and availability are favorable. Kraft pulping represented about 83% of the domestic pulp market in 1990. Public awareness about the environmental issue of nondegradable plastic packaging made many people prefer brown paper grocery bags (produced by the Kraft process), which degrade in landfills much more readily than plastic bags. Kraft pulping represents about 28% of the total demand for sodium sulfate.

Stocks

Yearend inventories of natural sodium sulfate stored by the three producers were 39,150 tons, which was a 63% increase over that of the previous year. The material stockpiled was anhydrous sodium sulfate. Synthetic sodium sulfate was marketed mainly through major chemical distributors, which have separate storage facilities from the producers.

Markets and Prices

A tightness in supply owing to Avtex Fiber's closure in 1989 caused the prices of available bulk and bagged sodium sulfate to increase. The average value rose from $91.55 per metric ton ($83.05 per short ton) in 1989 to $96.63 per metric ton ($87.66 per short ton) for bulk sodium sulfate, f.o.b. mine or plant. Kerr McGee Chemical Corp. (purchased by North American Chemical Co. later in the year) raised its bulk list price $5 per ton to $122 in April. Ozark Mahoning increased its list price by $5 to $105 per ton also in April.[3] Prior Chemical Corp. and Ashland Chemical Inc., two major chemical distributors, raised the bulk list price of byproduct sodium sulfate by $5 in February and saltcake prices by $10 later in the year.

Foreign Trade

Canada and Mexico represented about 89% and 11%, respectively, of total U.S. imports of sodium sulfate. Although the United States had a net import reliance of about 13%, most imports were less expensive to consumers than products from domestic sources, especially when overland shipping costs are considered.

U.S. exports of 62,000 tons were virtually the same in 1990 when compared with those of the previous year. About 53% of the total quantity was shipped to Australia; New Zealand received 17%; Thailand, 10%; and Colombia, 7%. Most was in the form of low-purity salt cake.

World Review

Industry Structure.—Approximately 52% of the world sodium sulfate production in 1990 was from natural sources; the remainder was represented by synthetic sodium sulfate recovered from various chemical and manufacturing processes. Although the U.S. Bureau of Mines collects or estimates data from 28 sodium sulfate-producing countries, other countries are known or assumed to have produced synthetic sodium sulfate, but production statistics are not reported, and available information is inadequate to make reliable estimates of output.

Capacity.—The data in table 2 are rated capacities for domestic natural operations and byproduct recovering facilities in 1990. Rated capacity is defined as the maximum quantity of product that can be produced in a period of time on a

TABLE 8

U.S. EXPORTS OF SODIUM SULFATE

(Thousand metric tons and thousand dollars)

Year	Disodium sulfate, salt cake[1]		Disodium sulfate, other[2]		Total[3]	
	Quantity	Value[4]	Quantity	Value[4]	Quantity	Value[4]
1986	97	8,218	5	1,965	101	10,183
1987	96	8,882	15	1,672	111	10,554
1988	62	5,128	15	3,609	77	8,737
1989	60	5,409	2	832	62	6,241
1990	61	6,092	1	612	62	6,704

[1]Prior to 1989, salt cake was Schedule B No. 4214200. In 1989, it was reclassified under the Harmonized Tariff System as HTS No. 2833111000.
[2]Prior to 1989, other sodium sulfate was Schedule B No. 4214500. In 1989, it is listed as HTS No. 2833115000.
[3]Data may not add to totals shown because of independent rounding.
[4]Customs, insurance, and freight (c.i.f.) value at U.S. ports.

Source: Bureau of the Census.

TABLE 9

U.S. EXPORTS OF SODIUM SULFATE, BY COUNTRY

Country	Disodium sulfate, salt cake[1]		Disodium sulfate, other[2]		Total	
	Quantity (metric tons)	Value[3] (dollars)	Quantity (metric tons)	Value[3] (dollars)	Quantity (metric tons)	Value[3] (dollars)
1989:						
Australia	33,483	3,448,712	—	—	33,483	3,448,712
Belgium	—	—	5	1,633	5	1,633
Brazil	—	—	7	22,049	7	22,049
Canada	82	15,700	120	30,559	202	46,259
Cayman	—	—	2	3,522	2	3,522
Chile	—	—	1	3,809	1	3,809
China	—	—	17	23,834	17	23,834
Colombia	4,142	364,505	—	—	4,142	364,505
Costa Rica	—	—	2	3,454	2	3,454
Denmark	—	—	5	11,660	5	11,660
Dominican Republic	—	—	281	69,826	281	69,826
Guyana	—	—	32	3,903	32	3,903
Germany, Federal Republic of	—	—	314	5,123	314	5,123
Haiti	—	—	37	22,820	37	22,820
Hong Kong	72	7,469	13	4,600	85	12,069
Honduras	—	—	35	37,428	35	37,428
Indonesia	5,207	312,429	17	3,800	5,224	316,229
Israel	—	—	1	2,467	1	2,467
Italy	—	—	14	97,800	14	97,800
Jamaica	—	—	(4)	1,502	(4)	1,502
Korea, Republic of	105	13,650	—	—	105	13,650
Mexico	3,079	256,578	395	154,759	3,474	411,337
New Zealand	7,941	543,992	(4)	2,153	7,941	546,145
Panama	—	—	(4)	2,634	(4)	2,634
Philippines	35	8,549	27	20,870	62	29,419

See footnotes at end of table.

TABLE 9—Continued

U.S. EXPORTS OF SODIUM SULFATE, BY COUNTRY

Country	Disodium sulfate, salt cake[1]		Disodium sulfate, other[2]		Total	
	Quantity (metric tons)	Value[3] (dollars)	Quantity (metric tons)	Value[3] (dollars)	Quantity (metric tons)	Value[3] (dollars)
1989—Continued						
Saudi Arabia	—	—	396	124,077	396	124,077
Singapore	—	—	1	2,608	1	2,608
Taiwan	—	—	42	134,987	42	134,987
Thailand	6,254	437,805	5	1,878	6,259	439,683
United Kingdom	—	—	18	13,137	18	13,137
Venezuela	—	—	7	10,902	7	10,902
Zimbabwe	—	—	16	13,935	16	13,935
Total	60,400	5,409,389	1,810	831,729	62,210	6,241,118
1990:						
Australia	32,628	3,468,288	—	—	32,628	3,468,288
Bahrain	—	—	9	19,358	9	19,358
Brazil	—	—	4	15,707	4	15,707
Canada	375	50,141	—	—	375	50,141
China	—	—	17	24,339	17	24,339
Colombia	4,418	246,519	—	—	4,418	246,519
Costa Rica	—	—	18	12,730	18	12,730
Denmark	—	—	5	11,660	5	11,660
Dominican Republic	—	—	138	40,721	138	40,721
France	—	—	4	17,280	4	17,280
Germany, Federal Republic of	—	—	5	12,325	5	12,325
Hong Kong	—	—	47	61,458	47	61,458
Indonesia	—	—	30	24,000	30	24,000
Italy	—	—	9	63,318	9	63,318
Japan	—	—	15	21,025	15	21,025
Korea, Republic of	5,586	633,418	—	—	5,586	633,418
Mexico	334	35,802	249	84,000	583	119,802
Netherlands	—	—	1	3,759	1	3,759
New Zealand	10,585	946,663	—	—	10,585	946,663
Panama	70	12,125	—	—	70	12,125
Portugal	—	—	103	63,280	103	63,280
Singapore	420	43,560	27	33,016	447	76,576
Spain	—	—	1	3,306	1	3,306
Switzerland	—	—	6	4,222	6	4,222
Taiwan	—	—	181	77,734	181	77,734
Thailand	6,205	639,117	—	—	6,205	639,117
United Kingdom	—	—	16	18,661	16	18,661
Venezuela	160	16,496	—	—	160	16,496
Total	60,781	6,092,129	885	611,899	61,666	6,704,028

[1]Prior to 1989, salt cake was Schedule B No. 42114200. In 1989, it was reclassified under the Harmonized Tariff System as HTS No. 2833111000.
[2]Prior to 1989, other sodium sulfate was Schedule B No. 4214500. In 1989, it is listed as HTS No. 2833115000.
[3]Free alongside ship (f.a.s.) value at U.S. ports.
[4]Less than 1/2 unit.

Source: Bureau of the Census.

TABLE 10

U.S. IMPORTS FOR CONSUMPTION OF SODIUM SULFATE

(Thousand metric tons and thousand dollars)

Year	Disodium sulfate, salt cake[1,2]		Disodium sulfate, other[3]		Total[4]	
	Quantity	Value[5]	Quantity	Value[5]	Quantity	Value[5]
1986	29	1,885	142	11,944	171	$13,829
1987	34	2,189	92	8,173	125	10,363
1988	27	1,930	109	10,034	136	11,962
1989	41	3,350	132	10,641	173	13,990
1990	40	3,277	122	9,879	162	13,155

[1]Beginning in 1989, import data were reclassified under the Harmonized Tariff System. Salt cake is HTS No. 2833111000. In prior years, salt cake was under TSUSA No. 4214200.
[2]Includes Glauber's salt as follows: 1986—38 tons ($9,175); 1987—666 tons ($38,318); and 1988—804 tons ($16,963). TSUSA No. was 4214600.
[3]Harmonized Tariff System No. 2833115000 in 1989, changed to No. 2833115010 in 1990; TSUSA No. 4214400 for prior years.
[4]Data may not add to totals shown because of independent rounding.
[5]Customs, insurance, and freight (c.i.f.) value at U.S. ports.

Source: Bureau of the Census.

TABLE 11

U.S. IMPORTS OF SODIUM SULFATE, BY COUNTRY

Country	Disodium sulfate, salt cake[1]		Disodium sulfate, other[2]		Total	
	Quantity (metric tons)	Value[3] (dollars)	Quantity (metric tons)	Value[3] (dollars)	Quantity (metric tons)	Value[3] (dollars)
1989:						
Brazil	148	20,216	—	—	148	20,216
Canada	33,133	2,593,418	110,336	9,081,486	143,469	11,674,904
Germany, Federal Republic of	—	—	42	20,821	42	20,821
Japan	622	79,383	—	—	622	79,383
Mexico	1,120	104,690	21,313	1,538,228	22,433	1,642,918
Sweden	1	5,754	—	—	1	5,754
United Kingdom	6,003	546,185	—	—	6,003	546,185
Total	41,027	3,349,646	131,691	10,640,535	172,718	13,990,181
1990:						
Brazil	122	21,045	—	—	122	21,045
Canada	40,117	3,220,484	103,164	8,584,982	143,281	11,805,466
Finland	28	9,794	—	—	28	9,794
Germany, Federal Republic of	14	1,426	—	—	14	1,426
Ireland	1	5,447	—	—	1	5,447
Japan	40	18,407	—	—	40	18,407
Mexico	—	—	18,179	1,293,881	18,179	1,293,881
Total	40,322	3,276,603	121,343	9,878,863	161,665	13,155,466

[1]Beginning in 1989, import data were reclassified under the Harmonized Tariff System. Salt cake is HTS No. 2833111000. In prior years, salt cake was under TSUSA No. 4214200.
[2]Harmonized Tariff System No. 2833115000 in 1989, changed to No. 2833115010 in 1990. TSUSA No. 4214400 for prior years.
[3]Customs, insurance, and freight (c.i.f.) value at U.S. ports.

Source: Bureau of the Census.

normally sustainable long-term operating rate, based on the physical equipment of the plant, and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that, in the judgment of the author, can be brought into production within a short period of time with minimum capital expenditure.

Mine capacity for natural sodium sulfate is derived from available company data on ore throughput to the refinery. The ore refers to mined crystalline sodium sulfate, harvested precipitate, or

TABLE 12

SODIUM SULFATE: WORLD PRODUCTION, BY COUNTRY[1]

(Metric tons)

Country[2]	1986	1987	1988	1989	1990[e]
Natural:					
Argentina	31,789	27,483	15,341	r10,281	11,000
Canada	370,726	342,076	r330,971	r369,500	370,000
Chile[3]	4,616	12,406	15,879	r10,000	10,000
China[e 4]	13,600	18,000	27,000	27,000	27,000
Egypt	18,940	42,484	e42,500	r45,677	45,000
Iran[e]	r123,000	r170,000	r214,000	r200,000	200,000
Mexico[5]	457,704	486,245	502,448	603,551	650,000
Netherlands[e]	18,000	22,000	22,000	22,000	22,000
South Africa, Republic of	466	241	r255	r15	20
Spain	450,911	475,255	e450,000	e450,000	460,000
Turkey[6]	r58,603	82,628	r79,427	r e80,000	80,000
U.S.S.R.[e 7]	345,000	365,000	375,000	365,000	365,000
United States	359,260	346,140	361,345	339,761	r349,256
Total	r2,252,615	r2,389,958	r2,436,166	r2,522,785	2,589,276
Synthetic:					
Austria[e]	55,000	109,000	118,000	120,000	120,000
Belgium[e]	265,000	260,000	255,000	255,000	250,000
Brazil[e]	7,000	7,000	9,000	9,000	9,000
Chile[9]	54,084	48,000	r47,000	r51,000	50,000
Finland[e]	35,000	35,000	35,000	35,000	35,000
France[e]	110,000	115,000	154,000	155,000	120,000
Germany, Federal Republic of:					
Eastern states	181,000	179,000	180,000	e175,000	175,000
Western states	163,000	164,000	e168,000	e175,000	175,000
Greece[e]	8,000	7,000	7,000	7,000	7,000
Hungary[e]	9,000	9,000	9,000	9,000	9,000
Italy[e]	75,000	80,000	127,000	130,000	130,000
Japan	253,450	255,313	246,541	r256,393	255,000
Netherlands[e]	15,000	15,000	15,000	15,000	15,000
Pakistan[e]	1,000	1,000	1,000	1,000	1,000
Portugal[e]	52,000	55,000	54,000	55,000	55,000
Spain[e 10]	150,000	165,000	165,000	165,000	160,000
Sweden[e]	100,000	100,000	100,000	100,000	100,000
Turkey[e]	27,000	27,000	27,000	27,000	27,000
U.S.S.R.[e 7]	260,000	260,000	270,000	270,000	270,000
United Kingdom[e]	90,000	90,000	90,000	90,000	90,000
United States[11]	403,662	391,541	r381,517	r345,555	r315,604
Yugoslavia	42,581	37,556	41,479	e40,000	40,000
Total	2,356,777	2,410,410	r2,500,537	r2,485,948	2,408,604
Grand total	r4,609,392	r4,800,368	r4,936,703	r5,008,733	4,997,880

[e]Estimated. [r]Revised.

[1]Table includes data available through Apr. 19, 1991.

[2]In addition to the countries listed, China, Norway, Poland, Romania, and Switzerland are known or are assumed to have produced synthetic sodium sulfate, and other unlisted countries may have produced this commodity, but production figures are not reported, and general information is not adequate for the formulation of reliable estimates of output levels.

[3]Natural mine output, excluding byproduct output from the nitrate industry, which is reported separately under "Synthetic" in this table.

[4]Byproduct sodium sulfate is known to be recovered but reliable data are not available; not included under "Synthetic."

[5]Series revised to show output as reported in the Annuario Estadístico de la Industria Química Mexicana, 1990 edition.

[6]Reported as concentrate. Run-of-mine production reported as, in metric tons: 1986—160,992; 1987—285,182; 1988—290,579; 1989—290,000 (estimated); and 1990—290,000 (estimated).

[7]Conjectural estimates based on 1968 information on natural sodium sulfate and general economic conditions.

[8]Reported figure.

[9]Byproduct of nitrate industry.

[10]Quantities of synthetic sodium sulfate credited to Spain are reported in official sources in such a way as to indicate that they are in addition to the quantities reported as mined (listed under "Natural" in this table), but some duplication may exist.

[11]Derived approximate figures; data presented are the difference between reported total sodium sulfate production (natural and synthetic not differentiated) and reported natural sodium sulfate sold by producers (reported under "Natural" in this table).

sodium sulfate-bearing brines. Refinery capacity for natural sodium sulfate pertains to the total amount of anhydrous sodium sulfate that the plant is capable of processing from the ore. Synthetic sodium sulfate-refining capacity is dependent on the production capabilities of the primary industry and the sodium sulfate recovery rates.

Canada.—Tonolli Canada Ltd. of Mississauga, Ontario, announced plans to recover sodium sulfate at its battery recycling operation. About 7,000 tons per year of high-purity sodium sulfate would be produced from spent sulfuric acid from the batteries.

Norway.—After the acquisition of Stora Kemi and Rana Kjemi in 1989, Eka Nobel commenced production at its new sodium sulfate facility at Mo i Rana. The plant has an annual production capacity of 25,000 tons. Access to inexpensive electrical energy was one important reason to construct the facility.[4]

OUTLOOK

Sodium sulfate production and consumption declined 36% and 33%, respectively, from those of 1980 to 1990. The decreases were because of changes in the recovery operations of consuming industries mandated by environmental legislation requiring reductions in sulfate emissions and declining use of sodium sulfate in powdered laundry detergents. Although production has been relatively flat since about 1982, domestic consumption of sodium sulfate has fluctuated primarily due to detergent reformulations that contain reduced quantities of sodium sulfate. U.S. consumption is expected to decline further, or least optimistically remain flat, in the next few years.

Less expensive imports from neighboring countries will continue to serve an important part of the needs of the domestic detergent and pulp and paper industries. Foreign producers dependent on sales to the United States may, however, encounter financial strain as domestic markets shrink. Canada, and possibly Mexico, may be affected by the declining demand for sodium sulfate within the United States. This could allow for more U.S. product to be produced and consumed within the United States.

Detergents

The use of sodium sulfate as a filler appears to have peaked in 1989. In 1990, major detergent manufacturers began reformulating to make superconcentrated detergent products rather than the traditional large boxes filled with bulk detergents containing up to 20% sodium sulfate as filler. This sudden change, initiated by environmental considerations, will further reduce sales of sodium sulfate in the near future unless consumers do not purchase the more-expensive superconcentrate detergents because of the higher cost. In addition, liquid laundry detergents that do not contain any sodium sulfate make up about 40% of the home laundry market.

Pulp and Paper

The economic recession that began in late-1990 had a slight affect on sodium sulfate sales to the pulp and paper sector, resulting in reduced sodium sulfate consumption. Environmental concerns regarding sulfur emissions prompted many Kraft pulpers to install pollution control equipment to reduce sulfur losses in the pulping process. One procedure using bipolar membranes recycles sodium sulfate and converts it to sulfuric acid and caustic soda, which was in short supply and expensive. The technology, developed by Allied-Signal Inc., has application in many pulp mills throughout the world.[5] Widescale use of this process may adversely affect the demand for sodium sulfate in the near future.

The paper industry has responded to the growing international environmental awareness by implementing alternate pulp bleaching technology. The pulp producers have been investigated for discharging carcinogenic wastewater effluents that contain certain dioxins and furans into the environment. Oxygen-based chemicals, such as sodium chlorate and hydrogen peroxide that are environmentally safe, are alternative pulp bleaching chemicals that may lessen the need for additional makeup sodium sulfate because the process generates byproduct sodium sulfate in the pulp liquor. Losses in sodium sulfate consumption may be partially offset by gains in sodium sulfate sales if the prices of caustic soda, which is an alternate pulping chemical, continues to increase, as many industry analysts forecast.

[1]Chemical and Engineering News. Facts and Figures for the Chemical Industry. V. 68, No. 25, p. 37.

[2]Chemical Week. Kerr McGee Sells Soda Products Business for $210 Million. V. 147, No. 24, p. 17.

[3]Chemical Marketing Reporter. Sodium Sulfate Is Healthy Despite Contracting Market. V. 238, No. 12, p. 32.

[4]European Chemical News. Na_2SO_4 Startup. V. 55, No. 1445, p. 9.

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